MISSOURI DEPARTMENT OF NATURAL RESOURCES
AIR AND LAND PROTECTION DIVISION
ENVIRONMENTAL SERVICES PROGRAM
Standard Operating Procedures

SOP #: MDNR-FSS-102 EFFECTIVE DATE: October 6, 2003

SOP TITLE: Field Analysis of Specific Conductance

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SUMMARY OF REVISIONS: Minor grammatical revisions were made along with the removal of a specific conductivity meter model that is no longer used by the ESP.

APPLICABILITY: The procedures outlined in this SOP apply to all ESP personnel who measure specific conductance in the field.

DISTRIBUTION: MoDNR Intranet
ESP SOP Coordinator

RECERTIFICATION RECORD:

Date Reviewed				
Initials				

1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure provides the Environmental Services Program (ESP) field personnel with guidance on the operation and maintenance of the various meters and how to conduct field analysis of conductivity during their field investigations.

2.0 BACKGROUND

2.1 Specific conductivity is measured between the opposing faces of a one-centimeter (cm) cube of liquid at a specific temperature. The specific conductance (hereinafter referred to as conductivity) of an aqueous solution depends upon the presence of ions – their total concentration, mobility, valence, and relative concentrations – and on the temperature of the solution.

2.2 All aqueous solutions conduct electricity to some degree. The measure of a solution's ability to conduct electricity is called "conductance" and is the reciprocal of resistivity (resistance). Adding electrolytes such as salts, acids or bases to pure water increases conductance (decreases resistivity) (Omega 1990/1991, *The pH and Conductivity Handbook*). Refer to Table I for the ranges of common aqueous solutions.

2.3 The standard unit of conductivity is "mhos/cm" where the unit mho is the reciprocal of the ohm. Therefore, the resistivity of 100 ohms/cm is equivalent to a conductivity of 1/100 mhos/cm. The Siemen (S) is an interchangeable international unit of measurement that is equivalent to the mhos/cm unit of measurement. In addition, conductivity is frequently expressed as milliSiemens/cm (mS/cm) and microSiemens/cm (μS/cm) (Omega 1990/1991, *The pH and Conductivity Handbook*). Therefore, the units used to define conductance and the relationships are as follows:

$$1/ohm = 1\ mho = 1\ Siemen(S) = 1000\ mS = 1{,}000{,}000\ \mu S$$

3.0 PERSONAL QUALIFICATIONS

Field personnel shall have a working knowledge of the field sample collection procedures and will have at a minimum either attended the department-sponsored inspection and enforcement training or received training from an MDNR employee knowledgeable of the proper sample collection procedures.

4.0 HEALTH AND SAFETY

4.1 The sample collector shall use an appropriate level of personal protection based on the specific work being done. The minimum level of personal protection to use is protective gloves and safety glasses. A more stringent level of protection may be required, such as those outlined in a site specific Health and Safety Plan, etc.

4.2 Field personnel should participate in the medical monitoring program in accordance with MDNR's medical monitoring policy. Those personnel routinely exposed to wastewater of domestic origin should be vaccinated for Hepatitis A as described in MDNR's Hepatitis A Prevention vaccine policy. This policy can be viewed on MDNR's intranet Health and Safety information page.

5.0 SAMPLING CONSIDERATIONS

5.1 The standard practice is to report conductivity values corrected to 25 degrees Celsius (°C). All of the conductivity meters and pens used by the ESP will automatically compensate for temperature differences between test solutions.

5.2 Conductivity increases with temperature at a rate of 2.1% / °C (refer to Orion meter instructional manuals). Therefore, if a conductivity meter does not compensate for temperature, the temperature of the solution must be recorded at the time of analysis (refer to MDNR-FSS-101, Field Measurement of Water Temperature).

5.3 Although a sample collected for conductivity analysis has a holding time of 28 days, conductivity is usually determined in the field using a portable conductivity meter or pen.

6.0 GENERAL OVERVIEW

6.1 The ESP uses various types of conductivity meters: Orion model 122, Orion model 125, and conductivity pens. All of the meters and pens will compensate to 25°C. The Orion model 125 conductivity meters and conductivity pens can be calibrated using a known standard. The Orion model 122 meter is factory calibrated and need only to be checked with a known standard to ensure accuracy. All of the meters and pens can be used to measure the conductivity of a water sample.

6.2 The meters and pens should be calibrated at least once per day just prior to the collection of field measurements. The meters and pens shall be calibrated according to the manufacturer's instructions using a known standard or an internal reference. If the meter has been factory calibrated, the meter should be checked for accuracy using a known standard solution.

6.3 The meters and pens should be calibrated or checked with the standard solution that is closest to the anticipated conductivity of the sample. In general, a lower standard should be used for surface water samples and a higher standard for mineralized groundwater, wastewater, and industrial samples.

6.4 The calibration procedures should always be documented in a field notebook (refer to MDNR-FSS-004, Field Documentation) for later reference.

7.0 PREPARATION OF CONDUCTIVITY STANDARD SOLUTIONS

7.1 Prepared conductivity standard solutions can be purchased from a scientific equipment vendor (i.e., Fisher Scientific or VWR Scientific) or prepared by ESP Water Quality Monitoring Section (WQMS) personnel.

7.2 Standard solutions should be prepared on a monthly basis and stored at room temperature in a tightly capped container, such as a Cubitainer, or a glass container (refer to Standard Methods for the Examination of Water and Wastewater, 20th Edition). Each container should be labeled with the solution's standard value, the date the solution was prepared and initials of the person who prepared the conductivity solution.

7.3 Standard solutions may be prepared as follows:

- Dissolve 745.6 mg anhydrous potassium chloride (KCl) in deionized water. Dilute to 1000 mL. This prepared solution will have a conductivity of 1413 µS/cm at 25°C.

- Dissolve 372.8 mg anhydrous KCl in deionized water. Dilute to 1000 mL. This prepared solution will have a conductivity of 706.5 µS/cm at 25°C.

- Dissolve 186.4 mg anhydrous KCl in deionized water. Dilute to 1000 mL. This prepared solution will have a conductivity of 353.25 µS/cm at 25°C.

7.4 If all three standards are being prepared simultaneously, a serial dilution can be used. Prepare 2 L of a 1413 µS/cm standard as stated above. Reserve 1000 mL of standard as 1413 µS/cm. Add 1000 mL of deionized water to the remaining liter to create the 706.5 µS/cm standard. Reserve 1000 mL of standard as 706.5 µS/cm. Add 1000 mL of deionized water to the remaining liter to create the 353.25 µS/cm standard.

7.5 A 1413 µS/cm conductivity calibration standard is prepared by the WQMS personnel and is stored within the conductivity meter cases. Conductivity standards 706.5 µS/cm and 353.25 µS/cm are also prepared and available if needed.

8.0 GENERAL CONDUCTIVITY MEASUREMENT PROCEDURES FOR ALL CONDUCTIVITY METERS USED BY ESP.

8.1 Immerse the conductivity cell in an adequate amount of sample solution to completely submerge the cell junctions. Expel all air bubbles by gently stirring the conductivity cell or by moving it up and down several times.

8.2 Wait for the reading to stabilize or until the meter indicates "READY".

8.3 If an unusual reading occurs, such as 1. ---, this is an indication the conductivity reading is higher than the chosen range setting. Choose another range setting and wait for the reading to stabilize.

8.4 Record the conductivity measurement on the Chain-of-Custody Record form (refer to MDNR-FSS-002, Field Sheet and Chain-of-Custody Record) and/or in the field personnel's field notebook.

8.5 To prevent cross contaminating a sample, the conductivity cell should be rinsed with deionized water after use and between measurements.

9.0 USING THE ORION MODEL 125 CONDUCTIVITY METER

9.1 This meter is characterized by a digital display, a keypad and a conductivity field cell. The advantage of using this type of meter is that it has a high degree of accuracy, automatic range selections (0.0 to 199.9 µS, 195 to 1999 µS, 1.95 to 19.99 mS and 19.5 to 199.9 mS) and a fast response time. The disadvantage is that if damaged, this type of meter is expensive to replace.

9.2 Along with measuring conductivity, this meter is capable of estimating the salinity and total dissolved solids (TDS) of a solution. This model calculates the salinity on the Practical Salinity Scale of 1978 (refer to the Orion meter's instructional manual), where the units to describe salinity are $^{0}/_{00}$ or ppt (parts per thousand). The conductivity meter can also be used to <u>estimate</u> the TDS by calculating the concentration of sodium chloride equivalent to a given conductivity and temperature value, where the unit to describe TDS is mg/L.

9.3 Field personnel should not use the TDS results as a replacement for the laboratory analysis of TDS, especially during an enforcement case.

9.4 Calibration Procedures for the Orion 125 Conductivity Meter

9.4.1 The power up checkout procedure should be followed prior to field use to ensure the meter's electronic and hardware components are in working order.

a. The conductivity cell should be disconnected or the meter will fail the hardware test during "Test 3" of the self diagnostic test.
b. Press and hold the YES key while pressing the ON/OFF key to turn meter on. The instrument automatically performs electronic and hardware diagnostic tests.
c. After Test 7, a "0" will appear on the display. Press each key (the numeric digits will change with each key press). All keys must be pressed within 4 seconds to complete "Test 7".
d. After the Test 7, the meter will display "Test 8" and then turn off.
e. If any problems are found during the self-test, the meter will display an operator assistance code until the YES key is pressed. Refer to the operation manual for a list of the operator assistance codes.
f. If the operator does not wish to perform the self-diagnostics checkout, the meter may be turned on by pressing the ON/OFF key.

9.4.2 This model of conductivity meter has three means of calibration. The meter may be calibrated by a cell constant adjustment method or by performing either the DirectCal or AutoCal methods.

- Cell constant adjustment: is performed by manually entering the cell constant of the cell then adjusting the cell constant by the percent error that is calculated by dividing the standard value by the displayed value for a given temperature.

- DirectCal: is performed by entering the desired conductivity range and then inputting the temperature corrected standard value(s). The meter automatically calculates the cell constant.

- AutoCal: is performed by entering the nominal cell coefficient and then measuring the calibration standard. When the reading stabilizes, the nominal calibration standard value is displayed. Whether using a temperature sensor or manual temperature, the meter corrects for the temperature internally.

9.4.3 For the ease of field calibration, the autocalibration method is the less complex of the three calibration procedures and is the preferred method of calibration. A summary version of the autocalibration method is included with each conductivity meter. For a description of the other calibration methods, please refer to Appendix A.

9.4.4 Meter Setup for Autocalibration:

a. Enter the SETUP mode by pressing the SETUP key.
b. Press the YES key until the autocalibration function is accessed. This is indicated by the SETUP code S-4.
c. Press a SCROLL key (the up or down arrow key) until the ON indicator is displayed. Press the YES key to activate the function.
d. To verify if the meter is set to automatically temperature compensate to 25°C, press the YES key until the temperature compensation mode is accessed. This is indicated by the SETUP code S-3.
e. If 25°C is not displayed, press a SCROLL key until 25°C is displayed then press the YES key to acknowledge the change.
f. The temperature coefficient should already be set at 2.1%/°C. To verify if the temperature coefficient is set correctly, press the YES key until code S-1 is displayed. Use the SCROLL key to change the value then press YES to accept the value.
g. Press the MODE key to exit the setup mode. The meter will return to the measurement mode.

9.4.5 Autocalibration Method:

a. Choose the appropriate standard that is closest to the expected conductivity of the sample (12.9 mS, 1413 µS or 100 µS). *Note: Only conductivity calibration standard 1413 µS is available within each meter case.*

b. Place the conductivity cell in the standard. Slightly agitate the conductivity cell to remove air bubbles.
c. Press the CAL key to initiate the calibration.
d. The current cell constant will then be displayed. This value may be accepted (if appropriate) or the cell constant may be changed to a nominal value (i.e. 1.0, 0.1 or 0.6) using the SCROLL key. Set the cell constant to 0.6.
e. The meter will then display P1 to indicate the first calibration point. While the meter is attempting to recognize the standard, dashes (----) will flash on the display.
f. When the meter recognizes a standard, the READY indicator will be displayed simultaneously with the nominal value of the recognized standard. If the conductivity cell input stabilizes without recognizing a standard, the dashes will stop flashing and the READY indicator will be displayed.
g. When the recognized standard value is displayed, press the YES key.
h. The meter will display P2 and dashes to indicate the second calibration point. If a two-point calibration is desired, rinse the conductivity cell and place it into the next calibration standard. Then repeat steps f and g.
i. If a one-point calibration is desired, press the MODE key.
j. After the last calibration standard has been entered, the meter will display the calculated cell constant then automatically return to the measurement mode.

10.0 USING THE ORION MODEL 122 CONDUCTIVITY METER

10.1 This meter is characterized by the digital display, two dials and a conductivity cell. One of the dials on the meter face is used to set the conductivity meter's range, the other is used to turn the meter on and off and to toggle back-and-forth from the conductivity reading to the temperature reading.

10.2 This meter has been pre-calibrated by the manufacturer and field calibration is not possible. Prior to conducting fieldwork or collecting a sample for conductivity, the meter needs to be checked for accuracy against a known conductivity standard.

10.3 This meter offers 4 ranges for conductivity measurements (0.0 to 199.9 µS/cm, 0 to 1999 µS/cm, 0.0 to 19.99 mS/cm and 0.0 to 199.9 mS/cm). To use the meter, use the conductivity range selector knob to select the optimum conductivity range for the sample. Then turn the Conductivity/Temperature selector knob from the off position to either the conductivity or temperature position to obtain the respective readings.

If the conductivity range selected is too low, the display will read "1" and a higher measurement range should be selected.

11.0 USING A CONDUCTIVITY PEN

11.1 The conductivity pen is simple to use, fairly accurate, and reliable. It is a good back-up system in case of meter malfunction. The pen is a low-cost piece of equipment and,

therefore, more appropriate to use on corrosive solutions or solutions containing products which may interfere with or damage a conductivity meter cell (e.g., petroleum products).

11.2 Unlike the other types of meters, the conductivity pen is susceptible to extreme environmental conditions (e.g., very hot or cold outdoor temperatures, rain or high humidity), static electricity, and/or interference from high voltage wires. In these cases, the pen will generally give erratic readings, will not stabilize or may be slow to stabilize to any one reading. Therefore, in instances where a high degree of accuracy is necessary, a conductivity meter should be used.

11.3 For calibration, use the following calibration instructions. For field reference, a copy of the calibration summary is included with each conductivity pen.

a. Remove the protective cap.
b. Turn on the conductivity pen by sliding the button located along the top of the pen.
c. Choose a conductivity solution that is closest to the expected conductivity of the sample.
d. Immerse the conductivity cell in the conductivity solution up to the maximum immersion (the indention line) level without touching the bottom of the beaker/container.
e. Stir gently and wait until the display stabilizes and using a small screwdriver turn the calibration trimmer to match the solution value.
f. The value on the display may or may not need to be multiplied by a factor of 10 or 100 depending upon the conductivity pen. The factor which the user will need to multiply to get direct readings in ppm or µS/cm, will be located in the upper left hand corner of the display.

12.0 QUALITY CONTROL

12.1 The conductivity meters and pens should be calibrated at least once a day just prior to the collection of field measurements. If numerous sites are monitored, the meters/pens should be rechecked in the conductivity calibration standard periodically throughout the day to ensure that the meter/pen is holding calibration.

12.2 The conductivity measurement should fall within 15% and preferably within 10% of the standard for the meter to be considered accurate.

12.2.1 If the meter is not able to fall within 15% of the standard, then the meter may need to be sent to the manufacturer for repairs or the conductivity cell may be fouled and may need to be replaced.

12.2.2 If the pen is not able to fall within 15% of the standard, then the pen should be discarded.

12.3 The ESP conductivity meters and pens are subjected to monthly QA/QC checks. The meters are calibrated and checked for accuracy by WQMS personnel using a known certified standard solution.

12.4 As part of quality control, all meters must be checked out and in by field personnel prior to field use. The following information shall be recorded on the equipment sign-out sheet: meter type(s) and property number(s), date meter(s) were checked out and returned, and the users name. Upon return from the field, field personnel shall record any problems/comments when using the meter in the comment section of the sign-out sheet.

13.0 REFERENCES

Hanna Instruments Dist-2 Pocket-Sized Conductivity Instruction Card.

MDNR-FSS-001, Required/Recommended Containers, Volumes, Preservatives, Holding Times and Special Sampling Considerations.

MDNR-FSS-002, Field Sheet and Chain-of-Custody Record.

MDNR-FSS-004, Field Documentation.

MDNR-FSS-005, General Sampling Considerations Including the Collection of Grab, Composite, and Modified Composite Samples from Streams and Wastewater Flows.

MDNR-FSS-101, Field Measurement of Water Temperature.

Omega 1990/1991, The pH and Conductivity Handbook

Orion Laboratory Products Group Model 122 Conductivity Meter Instruction Manual.

Orion Laboratory Products Group Model 125 and 150 Conductivity Meters Instruction Manual.

Standard Methods for the Examination of Water and Wastewater, 1998, 20th Edition, Section 2510.

APPENDIX A
Cell Constant Adjustment and DirectCal Calibration Methods

Cell Constant Adjustment Calibration Method:

1. Disable the temperature compensation and AutoCal functions by entering the SETUP mode. Scroll the temperature coefficient (S-1) down to 0 and press the YES key to accept the entry. Then access the AutoCal function (S-4) and scroll until the display reads "OFF" and press the YES key to accept the entry. Press the MODE key to return to measurement mode.
2. Initiate calibration by pressing the CAL key. The "Calibrate" indicator and the last cell constant will appear on the display.
3. Immerse the conductivity cell in the standard. Slightly agitate the cell to remove any air bubbles.
4. Enter the cell constant printed on the cell cable or refer to the instruments instruction manual on how to estimate the cell constant of the cell you are using. Use the SCROLL keys to move the decimal point, then press the YES key to accept the decimal placement. Enter the cell constant value by scrolling each digit with the SCROLL keys, then accepting the value by pressing the YES key. The meter automatically returns to the measurement mode.
5. Compare the displayed value of the standard to its specified value at the standard's temperature (see Table II).
6. If the correct standard value is not displayed, calculate the percentage error in the displayed value from step 4.

$$\text{Percent Error} = \frac{\text{Standard Value}}{\text{Displayed Value}}$$

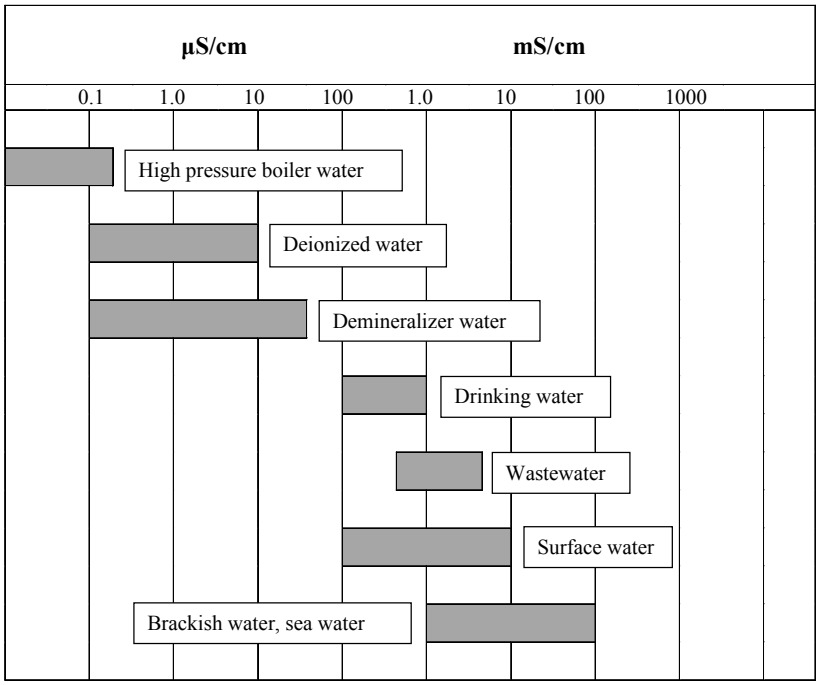
7. Return to step 2 and change the cell constant by this percentage.
8. Repeat steps 2 through 6 until the desired calibration accuracy is obtained.
9. Once the appropriate cell constant has been established, the temperature compensation feature may be enabled by changing the temperature coefficient in SETUP mode.

DirectCal Calibration Method:

1. Disable the temperature compensation and AutoCal functions by entering the SETUP mode. Scroll the temperature coefficient (S-1) down to 0 and press the YES key to accept the entry. Then access the AutoCal function (S-4) and scroll until the display reads "OFF" and press the YES key to accept the entry. Press the MODE key to return to measurement mode.
2. Initiate by pressing the CAL key twice. The "Calibrate" indicator will appear at the top center of the display while P1 is displayed to indicate the first calibration point.
3. Press the CAL key until the correct range for your standard appears on the display. The calibration ranges, 199.9 mS, 1999 µS and 199.9 µS, may be scrolled through multiple times by pressing the CAL key.
4. *(Note: The conductivity standard value should be 10% to 100% of the displayed range value. For example, 1413 µS would be in the 1999 µS range).*
5. Immerse the conductivity cell in the standard. Slightly agitate the cell to remove any air bubbles.
6. Enter the value of the standard by scrolling each digit with the SCROLL key, then accepting the value by pressing the YES key. Be sure to select the standard value at the actual standard temperature (see Table II).

7. After the last digit has been entered and accepted by pressing the YES key, the meter will check the input for a stable reading (indicated by the flashing CALIBRATE indicator). When stability is achieved, the READY indicator will light up followed by P2 (indicating the second calibration point).
8. If a two point calibration is desired, rinse the conductivity cell and place it into the next calibration standard. Then follow step 2 through 5 for the second point.
9. If a one point calibration is desired, press the MODE key when P2 is displayed.
10. The meter will perform the calibration, display the cell constant and return to the measurement mode.

TABLE I.
Ranges of Common Aqueous Solutions



1998, Orion Research, Inc., Instruction Manual for Models 125 and 150 Conductivity Meters

TABLE II.

Table of Conductivity vs. Temperature for the Cell Constant Adjustment and DirectCal Calibration Methods

TEMP °C	Conductivity Standard 1413 µS	TEMP °C	Conductivity Standard 1413 µS
0	776	26	1441
1	799	27	1468
2	822	28	1496
3	846	29	1524
4	870	30	1552
5	894	31	1580
6	918	32	1608
7	943	33	1636
8	968	34	1665
9	992	35	1693
10	1017	36	1722
11	1043	37	1751
12	1068	38	1780
13	1094	39	1808
14	1119	40	1837
15	1145	41	1866
16	1171	42	1896
17	1198	43	1925
18	1224	44	1954
19	1251	45	1983
20	1277	46	2013
21	1304	47	2042
22	1331	48	2071
23	1358	49	2101
24	1386	50	2103
25	1413		